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Realizing the increased potential of an open system high definition digital projector design

Reginald Daniels*

Air Force Research Laboratory
Mailing address: Visual Display Systems Branch
2255 H Street Bldg 248 Rm 300,
Wright Patterson AFB OH 45433-7022 USA

ABSTRACT

Modern video projectors are becoming more compact and capable. Various display technologies are very competitive and are delivering higher performance and more compact projectors to market at an ever quickening pace. However the end users are often left with the daunting task of integrating the "off the self projectors" into a previously existing system. As the projectors become more digitally enhanced, there will be a series of designs, as the digital projector technology matures. The design solutions will be restricted by the state of the art at the time of manufacturing. In order to allow the most growth and performance for a given price, many design decisions will be made and revisited over a period of years or decades. A modular open digital system design concept is indeed a major challenge of the future high definition digital displays for all applications.

Keywords: electronic displays, display projector, Common Large Area Display Set (CLADS), Head up Display (HUD), head down display, direct view display, space plane, direct view head down instrument panel, synthetic vision large area display projection displays, solid state laser projector and helmet mounted cueing for displays

1. INTRODUCTION

"Realizing the increased potential of an open system high definition digital projector design" will introduce and discuss the potential of a modular design approach. The advantages of a modular (open system) approach are numerous. Many display technologies that are available may be configured to be used in, interactive high definition display systems of the present and future, high definition video (studio class) equipment, high definition broadcast (terrestrial and satellite), and high definition theater equipment have common components and/or functions. A set of common digital projector modules will be discussed along with design variation potential of each module.

The advantages of modular open system approach include; increase number of options available to the end-user, increased standardization of the interfaces, and lower life cycle cost for maintenance are just a few. Enhanced hardware and software reuse, as well as accelerated development of "smart" modules for digital projector design. A modular design also enhances maintainability by increasing the number of potential solutions from multiple developers as well as allowing an increase in the number of component designers participating in the display market. The advantages listed above should all factor into the chief advantage of increasing the number of pragmatic options available to the end user.

Greater flexibility in managing the upgrading and/or maintenance of short life-cycle hardware components (projector components as well as projector models) is another advantage of the modular approach to digital projectors. Many hardware components have a redesign schedule that repeats once every eighteen months or sooner. Avionics system's (life cycle of 10 to 20 years) maintainability is therefore enhanced when a modular approach is established to administer these shorter life cycle subsystem components. Many of the current display projector designers and suppliers may be reorganized or merged

* *e-mail*: Reginald.Daniels@HE.wpafb.af.mil, *Telephone*: 937/255-8863, *Fax:* 937/255-8366

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into a different display market numerous times during the relative long life cycle of an avionics system (known as the vanishing vendor syndrome).

2. NEW DISPLAY TECHNOLOGIES?

Traditionally when one discussed high information content display it was very likely that the display was a cathode ray tube. Although cathode ray tube technology is currently the most mature and abundant display technologies in use today, it is by no means the only display technology. Display technology research is continuing in search of solutions for many of the current display technology shortcomings. Listed below in table 1 is a list of some of the newer display technologies as well as the display technology's relative performance advantage. The introduction of high definition broadcast has ushered in an era which the demand for increased addressable resolution (UXGA and above) low cost display technologies are in high demand.

Display technology name	Relative advantage
Cathode Ray Tube	mature tech, inexpensive, instant on
Field Emission Display	instant on, wide viewing angle
Organic Light Emitting Diode (arrays)	bright, wide viewing angle
Inorganic Light Emitting Diode	inexpensive, flexible
Grating Light Valve	inherent digitization, contrast, lumens
Digital MicroMirrow Device (also MEMS)	inherent digitization, contrast, lumens
Active Matrix Liquid Crystal (AMLCD)	mature, sunlight readable,
Electroluminescent	instant on, no standby power required
Laser	greater color rendering capability
Laser diode arrays	greater color rendering capability
Plasma	scalable to large areas display
Retinal Scanning devices	very high lumens to watts conversion
Cholestric LCD	zero power, night vision compatible
MEMs	very high lumens to watts conversion

Table I. Display technologies

Although many display technologies are listed in table one there are many display requirements that are not adequately addressed by any singular display technology. Sunlight readability, instant on, compatibility with subfreezing weather, and stand by power are only a few of the remaining issues to be solved for high information content displays. Since many of the operating environment requirements have not been solved concurrently, display manufactures are continuing to fund display research in the pursuit of a complete affordable one-technology solution.

3. CONFIGURATIONS AND TYPES OF AVIONICS PROJECTORS?

The scope of this paper will address modern video projectors as they are commonly applied in avionics systems. The various configurations and types of projectors are Head Up Display (HUD) shown in figure 2, direct view front screen projector, direct view rear screen projector as shown in figure 1., helmet-mounted display, retinal scanning displays, head-mounted displays, video wall and head down displays projectors.

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Other avionics projector designs incorporate the use of multiple projectors that are configured to perform, tiling , overlaying, or applying high resolution inserts in order to accomplish a visual scene. Figure 3. Visual Integrated Display is an example of a multi-projector system. Multi-projector systems are traditionally used when the visual system designer requires more addressable resolution than one projector is capable of adequately providing. There are many tasks that require eye limiting addressable resolution. When possible multiple projectors are configured to more closely approximate eye limiting resolution as with designs for high resolution video walls.

Figure 1. Raytheon DMD rear screen projector*

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Figure 2. Head Up Display** (HUD)

Figure 3. HUD view

** Pilot and Co-Pilot head-up displays shown as viewed from the cockpit

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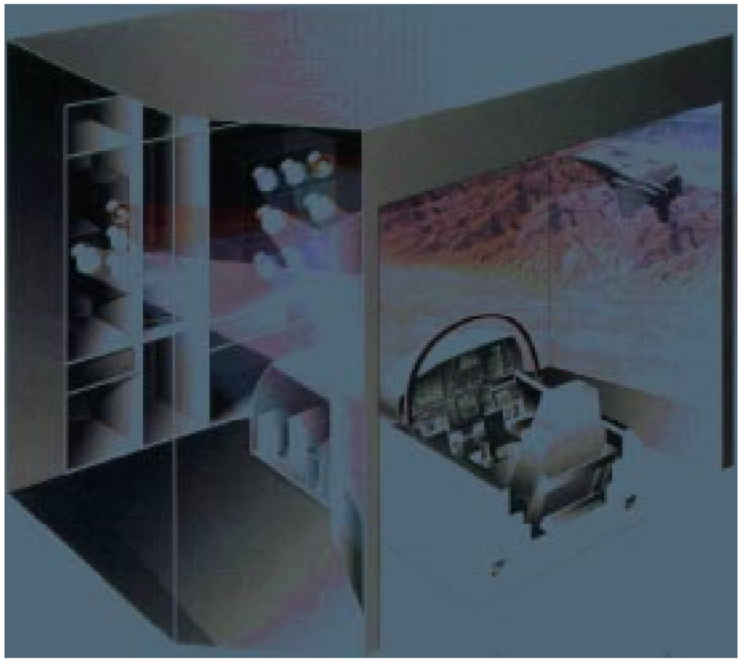

Figure 4. Visual Integrated Display (VID)* System

The major subsystems of a digital projector are the light creation section, light modulation, scanning, video interface, and the device driver section. Although these are the major subsystems and are common to most projector designs although these are not absolute modular division. Occasionally the light source and the light modulation are inherently indivisible. The cathode ray tube used as a light source and imaging source is an example of combining the light source and the light modulation. Newer display technologies may not be modular, in cases where an inherent physical structure of the technology prevents a modular subsystem interface to be readily accessible as noted with the cathode ray tube. Many projector designs unnecessarily inhabit or severely limit the end user from modifying or adjusting in any way the subsystems of the projector. The lack of a well-defined and/or standardized interface between the subsystems of the projector is a major contributor to the lack of interoperability among the projector subsystems.

The lack of a well-defined subsystem interface also prohibits the varied application of subsystems designed by different manufactures. The lack of a well-defined subsystem interface also may necessitates the redesign of the a complete projector systems when modifications occur in lighting sources, video interfaces, light modulators, or optics subsystems. The display industry is about to enter an era of major digitalization therefore many products will have countless upgrades within the relatively long (10 Years or more) avionics system lifecycle.

3.1 Typical subsystems of projectors and the potential digitization of the subsystems

The light creation subsection is typically were the electrical power is converted into lumens. A cathode ray tube (CRT) projector performs the light creation and modulation within the CRTs of the projector. In an active matrix liquid crystal display (AMLCD) projector, the light creation is typically performed by the metal halide lamp. In the digital micromirror

* VIDS is a Product of Boeing St Louis Simulation

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device and the grating light value, the light creation may be performed by a lamp also. Future areas of change for the "digitized" light creation section will be the development of smart light sources.

A smart light source would be able to perform dynamic color correction, as well synchronized light creation. The advantages of the synchronization of light creation would be increased contrast, while the dynamic color correction would allow a more accurate primary chromatics at various display intensities as well as a more accurate control of the primaries chromatics over the product lifetime.

Light emitting diodes, inorganic light emitting diodes and diode lasers all have a very short response time. Short response times allow the technologies to be used as synchronized light sources or combined with other technologies to perform a limited range of color balancing. In many instances, the increase digitization of a projector's light creation subsystems will allow for more accurate and more controlled light generation and management.

Light modulation in many designs suffers from large intensity losses due to polarizing filters. In particular light passing through multiple polarizers within a projector can be the source of inefficiency. A major function of the light polarizer is to separate the light into the primary colors in order to perform spatial light modulation or color sequential modulation. Potential advantages of an increased digitization projector would be a reduction in the losses occurring due to multiple passes through the polarizers. These losses could potentially be reduced by creating light only in the primary colors being applied and only at the instant that a specific primary color is needed in an image. The tremendous advantage to this technique would be the increased efficiency and increased contrast of the images produced by the digital projector system. Although polarizers may not be eliminated there use may be reduced, by using technologies that produced polarized light originally (organic lasers and organic led).

Advantages of a digitized scanning scheme would allow the end user to program the scanning, depending upon the projector application. Programmable scanning would allow multiple scans as well as changing the scan on the fly. Image overlays, and image inserts could implement in a manner that would take advantage of the sub-scanning techniques also.

Video interface for projectors is an area that is poised for substantially change in the future. The new era of high definition television will usher in digital television also. High definition television is just one of the possible digital television formats. Advances in various display technologies in the areas of chromatics, and addressable resolution will inevitably require trade off in the video interface subsystems. The traditional video interfaces will have the daunting task of addressing the increase in bandwidth and/or the compression of the future video data. The future video interfaces will also have to accommodate the larger color gamut of a laser light sources (resulting in increase color data) as well as the increasing addressable resolution capabilities.

Device drivers as well as the connectors between the device drivers and the light modulators are also effected by the increased digital data that will be displayed by the projectors of the future. Cross talk among connectors increases with higher bandwidth data being transferred through densely packed electronic leads. The designs that implement higher addressable resolutions within a smaller substrate have to accommodate a greater data bandwidth in a smaller physical space. As the physical space becomes smaller the secondary issues such as transparency, heat dissipation, bandwidth, and display manufacturing issues all summarize to become a major obstacles.

The optics subsystem is undergoing major changes because of advances and application of micro-electro-mechanical structures (MEMS) as well as advances in material sciences. Custom optics and coatings are becoming very common place as the infrastructure to develop these products becomes more mature. Research is being pursued with MEMS technology that may reduce or eliminate the need for polarizers (for color separation) in future projectors.

3.2 What are the major performance bottlenecks of a modern projector system?

Many performance issues are decided by "cost" as the primary factor. Cost as the primary factor is always anticipated to be an issue, but if the projector systems were compatible with a modular open system interface standard, the projector designs

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are expected to become more flexible (robust). The advantages of a more robust projector design is a projector that may be applied to a wider range of display applications. The wider range of display application is expected to created the volume sales to the display market. The volume increase in sales for the display products is expected to enabling a more pragmatic cost to the end user for display products.

Projector performance for avionics applications are limited in the following area; dynamic range of light output, maximum luminance, average luminance, low luminance level uniformity (near complete darkness), luminance uniformity, dynamic luminance range (10,000:1), analog perceptual difference, color depth, color uniformity, gray scale, contrast, color gamut, and viewing angles, night vision compatibility, resolution, flicker, cross talk, pixel fill, and sharpness. Many of the performance issues will be resolved with the newer display technology

Other deficiencies in the current projectors that have to be managed in a digital multi-projector systems are the color, color gamut, the chromaticity of the primarys, as well as the range of the color depth for a multi-projector system Ideally, all of the display technologies would have the exact same primary chromaticity. In practice however the primaries of different technologies will not have the same chromaticity or saturation.

Current projector display technology also has severely limited bandwidth restrictions on the data transferred through the projector video data interfaces. Future changes in the color capability of the light sources and digital color depths capability will require more color data to be transmitted to (maybe bi-directional) the digital projector. Although data compression is also a possible various situations prevent data compression from being applied to all designs. An increase in color depth, as well as increased range of brightness levels will place a increase data throughput of current state of the art video interfaces.

4. WHAT IS A MODULAR OPEN SYSTEM DESIGN APPROACH?

A modular system is a system in which the interfaces to the subsystems are defined, and the particulars of the subsystems are left to the discretion of the subsystem designers. The advantage of a modular open system approach is that it allows the subsystem designers the maximum flexibility in addressing the many design trade-off that are encountered in developing a subsystem. Other advantages of the modular system approach are the overall systems may become more complex and reliable because the structured modular approaches. One should be cautioned that modularity in and of itself is not a complete system design solution, it is just one of the tools that a systems engineer may implement to achieve the desired system product.

An ideal integrated system has no clear subsystems, open subsystem interface definitions or standard (consistent) subsystem interfaces. The various subsystem functions of a completely integrated (fused, mixed, or combined) subsystems is not restricted or structured in any systematic manner. Completely integrated systems are not modular from one version of the product to the next version of the product, or from one product to another product. The inherent advantage to this design approach is the lower up front cost associated with the design. The inherent disadvantage of this approach is the decreased system reliability due to single point failure, an increased long-term cost associated with unscheduled changes or modifications. Other disadvantages to a completely integrated system are the higher cost of maintenance and technical support for all of the various nonstandard versions.

An open system is a system in which the interface specifications are available to the public and are not proprietary and/or is a closed specification. Open system specifications should also be defined well enough that different manufactures using the open system specification "only" may develop working subsystems that are compatible and will interface to the other open system components and perform adequately.

4.1 Advantages of modular projector design?

What are the advantages of a modular digital projector design vs a non-modular digital projector design? Many functions of a digital projector are in the early stages of the "digital age" designs. Hardware and software products that are released in the early stages of a product's life cycle are prone to updates and changes. Although the analog electronics production environment has allowed implementation of form fit and function changes in the past, the digitally enhanced electronics

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(hardware and software) migration in electronics will vastly increase the number of discretely unique possibilities of changes. Changes in the design baseline should be expected and managed in a manner that allows the end user the greatest flexibility.

What are some digital projector subsystems that are most likely changes? Many of the projector's digital subsystems are poised for a revolutionary change. Examples of these areas include the light sources (color gamut, brightness, efficiency), digital video data interfaces (driven by increased color gamut, increase number of distinctly unique color possibilities, increased number of intensity levels, and higher addressable resolutions), and addressable resolution. Many of the areas listed above will eventually become "smart devices or subsystems" that will be allocated system resources and tasked to perform within the system in a "loosely coupled manner". The subsystem interface will supply limited power, timing, and data and these smart devices will according to there own internal algorithms performs the desired tasks within the allocated timeframe.

Another significant advantage of a modular open system digital projector design would be the ability to lower the entry cost of transitioning a product from design. Many intermediate steps and/or designs are necessary to bring a digital product to maturity. Many of the designs will be targeted for an ever changing market place. Therefore some of the designs will have to be revisited and reworked many times during the long avionics systems life cycle. When the projector products are modular, a complete system does not have to be designed before marketing a product. A manufacture has more options in addressing the ever changing display market.

The most significant advantage of a modular open system digital projector design would be the ability to leverage the large body of knowledge created by electro-optics research community. Transitioning research into a product is a process filled with various risks. Many add-on products that would utilize the large body of previously developed (for other projector and non-projector application) hardware and software would become possible. If a modular open system digital projector standards were implemented, the risk could be shared (ie multiple manufactures competing in sales of various subsystems). Many manufactures currently develop the complete analog projectors or major components of projectors. As the projectors become more digitized accurately assessing and predicting the sales within the projector market becomes more difficult.

Today it is possible to form a virtual company on the internet with employees dispersed around the world. These virtual companies are increasingly introducing products into the type of niche markets that a high performance digital projector may be categorized as. These virtual companies could bring an entrepreneurial spirit to address issues that larger corporations would not find profitable or within the company's targeted market area. A modular open system digital projector standard would truly enhance the development of digital projectors and digital projector components. The end user would benefit from an increase in the number of choice for digital projector, and digital projector components. The trade-off for this approach would require the end user to become more involved with the unique design aspects for the varied applications.

5. SUMMARY

Many advantages may be realized by developing and implementing an industry accepted modular open system digital projector standard. Current projectors do not address many brightness, color, addressable resolution and light source efficiency needs. An iteration of projector display designs will be developed in the future to address the large body of issues and trade-off regarding light sources, addressable resolution, optics, video interfaces, color matching among multi-display designs, etc. Many new display technologies will be applied to the digital display issues of tomorrow. The total cost of designing and manufacturing a complete projector design, for the total life cycle may become prohibitive to all but a few large companies. Many of the newer display technologies may be inserted into products more quickly with an open system modular standard. Hardware and software reusability is enhanced, as well as lowering of long term projector maintenance costs.

Why are display technologies of today inadequate? Avionics display applications using advanced sensor data are mismatched. Sensor resolution capability greater than display addressable resolution capability are occurring. Applying a more systematic approach to displaying the high information content of the new avionics sensors of today and tomorrow

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requires advances in toady's display technology. Much of the resolution of modern sensors will be misapplied or completely loss due to the inability of many of today's display systems to adequately accommodate sensor data.

There is an end-user need for many niche market applications of avionics open system high definition digital projectors. An open system high definition digital modular approach may become a technique that could enhance the transfer of electro-optics research into this projector products. The electro-optics research community has a body of previously developed work in software and/or hardware that may be applied more quickly and less costly to an open system digital projector designs. Transferring display research into products at a lower cost may yield greater competition and increase the variation in digital projector components available. Third party application of previously developed software and hardware should also be more easily applied to the digital projector designs.

With the advent of digital television (DTV) and high definition television (HDTV, which is also digital but at higher, 1920 x 1080 resolution) the transfer digital information within a display system will be a must in order to leverage the trend to digital TV by the consumer electronics market over the next decade and more. A major challenge of the high definition digitally enhanced displays will be an open systems approach that lends itself to modular, robustly re-configurable, components, and component system. A modular approach that would allows different devices designed by different manufactures to have access to a common system clock (sync), a common buss (data and/or control), and the device component could operate as a controller in the system, or be controlled by another component in the display projector system, would encourage many third party digital enhancements to be incorporated into the high definition digital projector.

Traditionally, a manufacture developed a projector as a self contained device with proprietary internal subsystems. The tremendous amount of change that will occur as the projector market becomes more digital may best be accommodated by means of an open system, modular, non proprietary digital projector system structure. Many components of an autoscopic (true 3-D) projector display, a high definition digital projector, and high definition television (both abroad) and in the USA, high definition video (studio class) equipment, high definition broadcast (terrestrial and satellite), and high definition theater equipment have common components and/or functions. The most costly of these components will be the software signal processing algorithms that will be controlling the internal subsystems of the high definition digital projector. Much of this software has already been developed for other applications and would lend itself to the many specialized applications that a digital projector system would allow the end user. There is an immediate need for other components that have not been designed as of yet. Many of the "smart components" will allow much greater capability than past projector systems. Capability such as interactive high definition displays have not progressed beyond a head tracker, or a mouse as a pointer. Far greater applications will have to be interactively integrated into the displays of tomorrow. In addition, the data entry points (for bi-directional interactive communication between the projection display and smart peripherals) have not been clearly established at this time.

As the digital high definition projectors become more digitally enhanced, there will be a series of designs, as the digital projector technology matures. Many of the design solutions will be restricted by the state of the art at the time of manufacturing. In order to allow the most growth and performance for a given price, many design decisions will be made and revisited over a period of years or decades. A modular open digital system is indeed a major challenge of the future high definition digital displays for all applications.

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